PACIFIC ECORISK | ENVIRONMENTAL CONSULTING & TESTING

Mr. Mark D'Avignon
U.S. Army Corps of Engineers
San Francisco District
1455 Market Street
San Francisco, CA 94103-1398

November 2, 2015

Dear Mr. D'Avignon:

As you may recall, the DMMO has requested that the Port of Redwood City (Port) estimate the potential for bioaccumulation of PAHs in Z-layer sediments (i.e., the post-dredge mudline) using the existing sediment and tissue PAH concentration data presented in the Sampling and Analysis Results (SAR) report "Characterization of the Sediment from the Port of Redwood City's Berths 1-4: Results of Dredge Materials Sampling and Analysis" which was presented at the July 8 DMMO meeting. The results of that initial Z-layer assessment were submitted to the DMMO on August 7, 2015.

Effects data were obtained from the Environmental Residue Effects Database (ERED) managed by the US Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC) to assess potential impacts of PAHs at the post-dredge mudline on the benthic community. The potential for effects was assessed by the development of Toxicity Reference Values (TRVs) using the ERED effects data; these TRVs were used as a screening tool to determine the potential for adverse impacts.

It has come to our attention that the effects data extracted from the ERED database that were used to derive the fluoranthene TRV value used in our assessment may be incorrect. Accordingly, we have obtained and reviewed the publication (Eertman et al 1995) that is cited as the source for the questionable data, and have determined the following:

- The ERED database tissue effect concentration that was used to derive the fluoranthene TRV value was identified as a reproductive effect; however, we were unable to identify any reported fluoranthene tissue effect concentrations (e.g., No Observable Effective Dose [NOED, Lowest Observable Effective Dose [LOED], ED50) relating to measured reproduction effects in the source publication;

- The paper does present effects data relating to clearance rates (volume of water cleared of suspended particles per unit of time) and the activity of the antioxidant enzymes superoxide dismutase (SOD) and catalase. These are both physiological and biochemical response endpoints, respectively, and the paper does present tissue effect concentrations (NOED, LOED, ED50) for these endpoints;

- While there was an anecdotal observation of gonadal development inhibition, neither gonad index classification data or fluoranthene tissue concentration data for which this observed effect occurred are reported, and thus no effect levels (NOED, LOED, ED50) can be established.

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The ERED database reports the following effects of fluoranthene tissue burdens on a wet weight (wt) basis:

- Physiological (clearance rate) LOED of 1500 μg/Kg fluoranthene, wet wt;
- Physiological (clearance rate) ED50 of 1900 μg/Kg fluoranthene, wet wt;
- Biochemical (enzyme activity) LOED of 1500 μg/Kg fluoranthene, wet wt; and
- Reproduction LOED of 220 μg/Kg fluoranthene (used for TRV development).

(It should be noted that the source publication presents the data on a dry wt basis and a conversion from dry wt to wet wt was performed prior to entry into the ERED; a review of the ERED and source publication data indicates that the tissue water content was assumed to be 80%).

Since the Eertman et al (1995) study was the ultimate source used to develop the fluoranthene TRV value used in our Z-layer assessment, and since that study primarily evaluated changes in "biochemical" or "physiological" activity resulting from fluoranthene exposure, it appears that the reproduction LOED entry in the ERED is either an error or incorrectly identifies the assessed effect as "reproduction" rather than physiological or biochemical. While we were unable to validate how a tissue LOED of 220 μg/Kg fluoranthene was determined, we were able to validate the remaining effect values listed in the ERED based upon the data presented in the source publication. As development of TRVs for this study is nominally limited to effects data reported in the ERED database that identify measurable biological effects [e.g., reduced survival, growth, or reproduction]), the use of "other" effects thresholds presented in Eertman et al (1995) for establishing a TRV would not be appropriate.

Attached is our revised Z-layer assessment for the Port of Redwood City that reflects the use of the next-most-sensitive fluoranthene TRV. When this TRV is applied as the screening benchmark to asses modeled Z-layer fluoranthene tissue concentrations, the results indicate that none of the *Macoma* or *Nereis* measured tissue fluoranthene concentrations would exceed the TRV.

It should be noted that while there were no excedances of the benzo(a)pyrene TRV in our current assessment, the data obtained from the ERED used to develop the benzo(a)pyrene TRV were also based on Eertman et al (1995), and similarly, the reported effects data for this compound were for "biochemical" or "physiological" activity resulting from benzo(a)pyrene exposure and not reproduction. As a result, the next most-sensitive benzo(a)pyrene TRV is presented in this revised assessment.

Based on the identification of an error in the ERED database, and the application of a more correct TRV, it appears that there may not be a need to perform post-dredging sampling and testing of the Port of Redwood City Z-layer. I will follow-up and give you a call once you have had a chance to take a look at this.

If you have any questions, please give me a call at (707) 207-7761. I look forward to hearing from you.

Sincerely,

Jeffrey Cotsifas
President

(cc w/enc): Mr. Robert Lawrence
Mr. Brian Ross, U.S. EPA
Ms. Brenda Goeden, BCDC
Ms. Elizabeth Christian, SFRWQCB
Mr. Don Snaman, Port of Redwood City
Ms. Jaclyn Gnusti, Moffatt & Nichol
Mr. Jack Fink, Moffatt & Nichol

1. INTRODUCTION

The Sampling and Analysis Results (SAR) report "Characterization of the Sediment from the Port of Redwood City's Berths 1-4: Results of Dredge Materials Sampling and Analysis" was presented at the recent July 8, 2015, DMMO meeting. At that meeting, the DMMO determined that the proposed dredged material from the Port of Redwood City Berths 1&2 (comprising Dredge Unit 1 [DU1]) would be suitable for placement at the San Francisco Bay Deep Ocean Disposal site (SF-DODS) or as foundation material at the Montezuma Wetlands Restoration Program (MWRP). It was also determined that Berths 3&4 (DU2) sediment would be suitable for in-Bay placement at SF-11, the San Francisco Bay Deep Ocean Disposal site (SF-DODS), or as MWRP foundation material. However, as the reported total PAH concentrations in the DU2 "Z-layer" sediment composite sample and in the majority of the DU2 "Z-layer" individual core samples were above the total PAH concentration measured in the proposed dredged material, the DMMO requested that the Port estimate the potential for bioaccumulation of PAHs from these sediments using the existing sediment and tissue PAH concentration data presented in the SAR. This information would be used to support Port of Redwood City permitting activities.

Bioaccumulation potential was assessed using the following approach:

1. Site-specific biota-sediment accumulation factors (BSAF) were determined for the Port of Redwood City sediments using paired measured sediment PAH and tissue PAH concentrations (PER 2015);

2. BSAFs were determined for acenaphthene, benzo(a)pyrene, fluoranthene, phenanthrene, and pyrene, the PAH compounds for which tissue toxicity reference values (TRV) were established in the SAR (PER 2015) and for which effects data are available from the USACE ERED database (http//wes.army.mil/el/ered/index.html; 2014);

3. The theoretical bioaccumulation potential (TBP) for each of these PAHs in the PRC-DU2-Z-Comp and PRC-DU2 individual Z-layer samples was calculated using the site-specific BSAFs;

4. As the 28-day bioaccumulation test results may underestimate steady-state levels, the 28-day TBP results were adjusted to represent steady-state conditions; and

5. The steady-state corrected TBP estimates for the PRC-DU2-Z-Comp and PRC-DU2 individual Z-layer samples were compared to the tissue toxicity reference values (TRV) established in the SAR (PER 2015).

The results of this assessment are provided in the following sections.

1.1 Calculation of a Site Specific Biota-Sediment Accumulation Factor (BSAF)

A BSAF is a model describing bioaccumulation of sediment-associated organic compounds or metals into tissues of ecological receptors (EPA 2009). The BSAF is calculated from four measured variables (see Equation 1 below):

- ***C*o** is the concentration of the chemical in the organism on a wet weight basis (µg/kg wet weight [ww]),
- ***f*l** is the lipid content of the wet tissue (g lipid/g ww),
- ***C*s** is the concentration of the chemical in the sediment on a dry weight basis (µg/kg dry weight [dw]), and
- ***f*soc** is the organic carbon content of the dry sediment (g organic carbon/g dw).

Equation #1:

$$BSAF = \frac{C_O/f_l}{C_S/f_{soc}}$$

Site-specific BSAFs for acenaphthene, benzo(a)pyrene, fluoranthene, phenanthrene, and pyrene were determined using measured sediment and tissue data from the most recent Port of Redwood City testing program (PER 2015). These data are presented in Tables 1(a-c), below. As the *Nereis virens* tissue PAH concentrations for acenaphthene, benzo(a)pyrene, and phenanthrene were reported as "not detected" (Table 1a), the method detection limit was used to calculate the site specific *N. virens* BSAF for each of these compounds; the resulting tissue concentration estimates used for *N. virens* are therefore considered conservative. The calculated BSAFs are presented in Table 2.

Table 1a. Port of Redwood City Sediment Measured PAH Concentrations.

Analyte	Sediment Concentrations (µg/kg dw)					
	Acenaphthene	Benzo(a)pyrene	Fluoranthene	Phenanthrene	Pyrene	**Total PAHs[A]**
PRC-DU2	72	610	41 J	320	1200	**6,597[B]**
PRC-DU2-Z	150	800	1400	360	1400	**9,207[B]**
PRC-DU2-Z-01	640	1200	4600	1500	4200	**22,001[B]**
PRC-DU2-Z-02	12 J	510	300	120	740	**4,562[B]**
PRC-DU2-Z-03	59 J	1000	3100	380	2600	**14,225[B]**
PRC-DU2-Z-04	140	1800	17000	740	14000	**54,236[B]**
PRC-DU2-Z-05	nd (27)	860	600	170	1400	**7,711[B]**

A - Total PAHs are the sum of the RMP 25 reported in PER 2015.

B - Above San Francisco Bay Bioaccumulation total PAHs (RMP 25) Trigger Level of 4500 µg/kg (USACE/USEPA 2011, SFEI 2015).

J - Analyte was detected at a concentration below the laboratory reporting limit and above the laboratory method detection limit; the reported value is therefore an estimate.

nd - Not detected (method detection limit shown in parentheses).

Table 1b. Port of Redwood City PRC-DU2 Tissue Measured PAH Concentrations.

Species	Tissue Concentrations (µg/kg ww)					
	Acenaphthene	Benzo(a)pyrene	Fluoranthene	Phenanthrene	Pyrene	**Total PAHs[A]**
M. nasuta	3.00 J	17.0	170	17.0	180	**552[B]**
N. virens	nd (2.6)	nd (2.6)	5.10	nd (2.6)	4.0 J	**9.10[B]**

A - Total PAHs are the sum of the RMP 25 reported in PER 2015.

B - Above San Francisco Bay Bioaccumulation total PAHs (RMP 25) Trigger Level of 4500 µg/kg (USACE/USEPA 2011, SFEI 2015).

J - Analyte was detected at a concentration below the laboratory reporting limit and above the laboratory method detection limit; the reported value is therefore an estimate.

nd - Not detected (method detection limit shown in parentheses).

Table 1c. Port of Redwood City Sediment TOC and Tissue Lipid Concentrations.

Analyte	**Sediment Concentrations (% dw)** = g organic carbon/g dw		**Tissue Concentrations (% ww)** = g lipids/g ww	
	PRC-DU2	**PRC-DU2 and Individual Z-layer cores**	**PRC-DU2**	
			M. nasuta	***N. virens***
Total Organic Carbon	2.0	1.9	-	-
Lipids	-	-	0.59	2.0

Table 2. Calculation of Port of Redwood City Site-Specific PAH BSAFs.

Dredge Unit =		**PRC-DU2**	
Bioaccumulation Test Species =		*M. nasuta*	*N. virens*
Sediment TOC (% dw)[A] =		2.0	
Tissue Lipid (% ww)[B] =		0.59	2.0
Acenaphthene	Sediment Concentration[C]	72	
	28 day Tissue Concentration[D]	3.00	2.60[E]
	BSAF =	0.14	0.036
Benzo(a)pyrene	Sediment Concentration[C]	610	
	28 day Tissue Concentration[D]	17.0	2.60[E]
	BSAF =	0.09	0.004
Fluoranthene	Sediment Concentration[C]	960	
	28 day Tissue Concentration[D]	170	5.10
	BSAF =	0.60	0.005
Phenanthrene	Sediment Concentration[C]	320	
	28 day Tissue Concentration[D]	17.0	2.60[E]
	BSAF =	0.18	0.008
Pyrene	Sediment Concentration[C]	1200	
	28 day Tissue Concentration[D]	180	4.0
	BSAF =	0.51	0.003

A - g organic carbon/g dw.

B - g lipids/g ww.

C - µg/kg dw.

D - µg/kg ww.

E - As the concentration reported for this compound was reported as "nd" (Table 1a) for this compound, the method detection limit was used to calculate the site-specific *N. virens* BSAF; the results are considered conservative.

1.2 Theoretical Bioaccumulation Potential of DU2 (Berths 3&4) Z-Layer Samples

Since bioaccumulation testing was not performed on the PRC-DU2-Z-Comp or PRC-DU2 individual Z-layer samples, the TBPs for the PAHs in the Z-layer sediments were calculated using site-specific BSAFs derived from paired measured acenaphthene, benzo(a)pyrene, fluoranthene, phenanthrene, and pyrene sediment and tissue concentrations for the PRC-DU2 maintenance depth sediments (Section 1.1), and the measured PRC-DU2-Z and individual Z-layer sample PAH concentrations and total organic carbon (Tables 1a and 1b). The TBPs were calculated using Equation #2 (below); the results of these calculations are presented in Tables 3a and 3b:

Equation #2:

$$TBP = BSAF\ (C_S/\%TOC)\ \%L$$

where TBP is expressed on a whole-body wet-weight basis in the same units as C_S and:

C_S = PAH analyte concentration measured in the sediment sample;

BSAF = site-specific factor derived from measured paired sediment PAH and tissue PAH values from sediments collected from PRC-DU2;

%TOC = TOC concentration measured in the sediment sample; and

%L = *Macoma nasuta* and *Nereis virens* measured lipid content.

1.3 Comparison of Predicted Z-layer Tissue Concentrations to Toxicity Reference Values

As the TBP results were based on 28-day bioaccumulation test data and may not represent "steady-state" conditions for the PAHs compounds evaluated, an estimation of steady-state was performed for each compound using available information (ASTM 2013, USACE 2010, and USEPA/USACE 1998) prior to comparison to TRV values. TRV values were selected as described in PER 2015 and are presented on Table 4; for each compound evaluated, the lowest TRV was selected, regardless of species, to ensure that a conservative screening was applied. For the PRC-DU2-Z-Comp sediment, none of the predicted *M. nasuta* or *N. virens* PAH tissue concentrations exceeded TRV values. Summaries of the selected TRV values relative to the predicted test organism tissue concentrations in each sample are presented in Table 5.

Table 3a. Predicted Bioaccumulation of PAHs in Port of Redwood City Z-Layer Samples in *Macoma nasuta* Tissues: Results of TBP Calculations.

		Acenaphthene	Benzo(a)pyrene	Fluoranthene	Phenanthrene	Pyrene
Sediment TOC (% dw) [A] =		1.9				
Tissue Lipid (% ww) [B] =		0.59				
BSAF =		0.14	0.09	0.60	0.18	0.51
PRC-DU2-Z-Comp	Sediment Concentration[C] =	150	800	1400	360	1400
	TPB[D] =	**6.52**	**22.36**	**261**	**20.12**	**221.72**
PRC-DU2-01-Z	Sediment Concentration[C] =	640	1200	4600	1500	4200
	TPB[D] =	**27.82**	**33.54**	**857**	**83.84**	**665**
PRC-DU2-02-Z	Sediment Concentration[C] =	12	510	300	120	740
	TPB[D] =	**0.52**	**14.25**	**55.89**	**6.71**	**117.19**
PRC-DU2-03-Z	Sediment Concentration[C] =	59	1000	3100	380	2600
	TPB[D] =	**2.56**	**27.95**	**578**	**21.24**	**411.76**
PRC-DU2-04-Z	Sediment Concentration[C] =	140	1800	17000	740	14000
	TPB[D] =	**6.09**	**50.31**	**3167.37**	**41.36**	**2217.16**
PRC-DU2-05-Z	Sediment Concentration[C] =	27	860	600	170	1400
	TPB[D] =	**1.17**	**24.03**	**112**	**9.50**	**221.72**

A - g organic carbon/g dw.

B - g lipids/g ww.

C - μg/kg dw.

D - TBP = Theoretical Bioaccumulation Potential (μg/kg ww).

Table 3b. Predicted Bioaccumulation of PAHs in Port of Redwood City Z-Layer Samples in *Nereis virens* Tissues: Results of TBP Calculations.

		Acenaphthene	Benzo(a)pyrene	Fluoranthene	Phenanthrene	Pyrene
Sediment TOC (% dw) [A] =		1.9				
Tissue Lipid (% ww) [B] =		2.0				
BSAF =		0.036	0.004	0.005	0.008	0.003
PRC-DU2-Z-Comp	Sediment Concentration[C] =	150	800	1400	360	1400
	TPB[D] =	**5.68**	**3.37**	**7.37**	**3.03**	**4.42**
PRC-DU2-01-Z	Sediment Concentration[C] =	640	1200	4600	1500	4200
	TPB[D] =	**24.2**	**5.05**	**24.2**	**12.6**	**13.3**
PRC-DU2-02-Z	Sediment Concentration[C] =	12	510	300	120	740
	TPB[D] =	**0.45**	**2.15**	**1.58**	**1.01**	**2.34**
PRC-DU2-03-Z	Sediment Concentration[C] =	59	1000	3100	380	2600
	TPB[D] =	**2.24**	**4.21**	**16.3**	**3.20**	**8.21**
PRC-DU2-04-Z	Sediment Concentration[C] =	140	1800	17000	740	14000
	TPB[D] =	**5.31**	**7.58**	**89.5**	**6.23**	**44.2**
PRC-DU2-05-Z	Sediment Concentration[C] =	27	860	600	170	1400
	TPB[D] =	**1.02**	**3.62**	**3.16**	**1.43**	**4.42**

A - g organic carbon/g dw.

B - g lipids/g ww.

C - μg/kg dw.

D - TBP = Theoretical Bioaccumulation Potential (μg/kg ww).

Table 4. Summary of ERED Tissue PAH 'Effect' Concentrations Used to Determine Potential Benthic Impacts.

PAH	Species	Reported "Effects" Concentration (µg/kg ww)	TRV (µg/kg ww)	Type of Effect	Toxicity Endpoint	Lifestage	Reference
Acenaphthene	*Mytilus edulis*	29,400	**1,470[A]***	behavior	ED50	adult	Donkin et al 1989
Benzo(a)pyrene	*Asterias rubens*	10,000	**10,000***	reproduction	LOED	adult	den Besten et al. 1993
Fluoranthene	*Capitella sp.*	43,800	43,800	growth	NOED	adult	Bach et al. 2005
Fluoranthene	*Mytilus edulis*	627,000	31,350 [A]	behavior	ED50	adult	Donkin et al 1989
Fluoranthene	*Streblospio benedicti*	73,140	**3,650[A]***	mortality	LR50	adult	Weinstein and Singer 2003
Phenanthrene	*Mytilus edulis*	30,700	1,535[A]	behavior	ED50	adult	Donkin et al 1989
Phenanthrene	*Nereis arenaceodentata*	780	780	behavior	LOED	immature	Emery et al. 1996
Phenanthrene	*Nereis arenaceodentata*	780	780	growth	LOED	immature	Emery et al. 1996
Phenanthrene	*Nereis arenaceodentata*	780	**780***	reproduction	LOED	immature	Emery et al. 1996
Phenanthrene	*Nereis arenaceodentata*	780	780	mortality	NOED	immature	Emery et al. 1996
Pyrene	*Mytilus edulis*	189,000	**9,450[A]***	behavior	ED50	adult	Donkin et al 1989

ED = Effect Dose; LD = Lethal Dose; LOED - lowest observed effect dose; NOED = no observed effect dose.
* For each of the PAHs, the most sensitive "Effects" Concentration selected for use in TRV development.
[A]TRV was calculated by applying an uncertainty factor of 20 to the reported ED50 value to (USACHPPM 2000).

Table 5. Comparison of Steady-State Corrected *Macoma nasuta* and *Nereis virens* Tissue Concentrations to the USACE ERED Database-Derived Toxicity Reference Values.

Site	Species	Chemical	Predicted Mean Tissue Concentration (µg/kg, wet wt)	Steady State Correction Factor	Steady State Corrected Mean Tissue Concentration (µg/kg, wet wt)	TRV (µg/kg, wet wt)	Exceedance of TRV?
PRC-DU2-Z-Comp	*M. nasuta*	Acenaphthene	6.52	1.00[A]	6.52	1,470	no
		Benzo(a)pyrene	22.36	1.02[B]	22.81	10,000	no
		Fluoranthene	260.84	1.03[C]	268.67	3,650	no
		Phenanthrene	20.12	1.00[C]	20.12	780	no
		Pyrene	221.72	1.13[C]	250.54	9,450	no
	N. virens	Acenaphthene	5.68	1.00[A]	5.68	1,470	no
		Benzo(a)pyrene	3.37	2.00[A]	6.74	10,000	no
		Fluoranthene	7.37	1.00[D]	7.37	220	no
		Phenanthrene	3.03	1.00[A]	3.03	780	no
		Pyrene	4.42	1.00[E]	4.42	9,450	no
PRC-DU2-01-Z	*M. nasuta*	Acenaphthene	27.82	1.00[A]	27.82	1,470	no
		Benzo(a)pyrene	33.54	1.02[B]	34.21	10,000	no
		Fluoranthene	857.05	1.03[C]	882.76	3,650	no
		Phenanthrene	83.84	1.00[C]	83.84	780	no
		Pyrene	665.15	1.13[C]	751.62	9,450	no
	N. virens	Acenaphthene	24.25	1.00[A]	24.25	1,470	no
		Benzo(a)pyrene	5.05	2.00[A]	10.11	10,000	no
		Fluoranthene	24.21	1.00[D]	24.21	220	no
		Phenanthrene	12.63	1.00[A]	12.63	780	no
		Pyrene	13.26	1.00[E]	13.26	9,450	no

Table 5 (*continued*). Comparison of Steady-State Corrected *Macoma nasuta* and *Nereis virens* Tissue Concentrations to the USACE ERED Database-Derived Toxicity Reference Values.

Site	Species	Chemical	Predicted Mean Tissue Concentration (µg/kg, wet wt)	Steady State Correction Factor	Steady State Corrected Mean Tissue Concentration (µg/kg, wet wt)	TRV (µg/kg, wet wt)	Exceedance of TRV?
PRC-DU2-02-Z	*M. nasuta*	Acenaphthene	0.52	1.00[A]	0.52	1,470	no
		Benzo(a)pyrene	14.25	1.02[B]	14.54	10,000	no
		Fluoranthene	55.89	1.03[C]	57.57	3,650	no
		Phenanthrene	6.71	1.00[C]	6.71	780	no
		Pyrene	117.19	1.13[C]	132.43	9,450	no
	N. virens	Acenaphthene	0.45	1.00[A]	0.45	1,470	no
		Benzo(a)pyrene	2.15	2.00[A]	4.29	10,000	no
		Fluoranthene	1.58	1.00[D]	1.58	220	no
		Phenanthrene	1.01	1.00[A]	1.01	780	no
		Pyrene	2.34	1.00[E]	2.34	9,450	no
PRC-DU2-03-Z	*M. nasuta*	Acenaphthene	2.56	1.00[A]	2.56	1,470	no
		Benzo(a)pyrene	27.95	1.02[B]	28.51	10,000	no
		Fluoranthene	577.58	1.03[C]	594.91	3,650	no
		Phenanthrene	21.24	1.00[C]	21.24	780	no
		Pyrene	411.76	1.13[C]	465.29	9,450	no
	N. virens	Acenaphthene	2.24	1.00[A]	2.24	1,470	no
		Benzo(a)pyrene	4.21	2.00[A]	8.42	10,000	no
		Fluoranthene	16.32	1.00[D]	16.32	220	no
		Phenanthrene	3.20	1.00[A]	3.20	780	no
		Pyrene	8.21	1.00[E]	8.21	9,450	no

Table 5 (*continued*). Comparison of Steady-State Corrected *Macoma nasuta* and *Nereis virens* Tissue Concentrations to the USACE ERED Database-Derived Toxicity Reference Values.

Site	Species	Chemical	Predicted Mean Tissue Concentration (µg/kg, wet wt)	Steady State Correction Factor	Steady State Corrected Mean Tissue Concentration (µg/kg, wet wt)	TRV (µg/kg, wet wt)	Exceedance of TRV?
PRC-DU2-04-Z	*M. nasuta*	Acenaphthene	6.09	1.00[A]	6.09	1,470	no
		Benzo(a)pyrene	50.31	1.02[B]	51.31	10,000	no
		Fluoranthene	3167.37	1.03[C]	3262.39	3,650	no
		Phenanthrene	41.36	1.00[C]	41.36	780	no
		Pyrene	2217.16	1.13[C]	2505.39	9,450	no
	N. virens	Acenaphthene	5.31	1.00[A]	5.31	1,470	no
		Benzo(a)pyrene	7.58	2.00[A]	15.16	10,000	no
		Fluoranthene	89.47	1.00[D]	89.47	3,650	no
		Phenanthrene	6.23	1.00[A]	6.23	780	no
		Pyrene	44.21	1.00[E]	44.21	9,450	no
PRC-DU2-05-Z	*M. nasuta*	Acenaphthene	1.17	1.00[A]	1.17	1,470	no
		Benzo(a)pyrene	24.03	1.02[B]	24.52	10,000	no
		Fluoranthene	111.79	1.03[C]	115.14	3,650	no
		Phenanthrene	9.50	1.00[C]	9.50	780	no
		Pyrene	221.72	1.13[C]	250.54	9,450	no
	N. virens	Acenaphthene	1.02	1.00[A]	1.02	1,470	no
		Benzo(a)pyrene	3.62	2.00[A]	7.24	10,000	no
		Fluoranthene	3.16	1.00[D]	3.16	3,650	no
		Phenanthrene	1.43	1.00[A]	1.43	780	no
		Pyrene	4.42	1.00[E]	4.42	9,450	no

TRV = Toxicity Reference Value (PER 2014)

A - Based on assessment of K_{ow} (USACE/USEPA 1998).

B - Average for *Macoma nasuta* as reported in USACE 2010.

C - Average for *Macoma nasuta* as reported in ASTM E1688 and USACE 2010.

D - Average for *Neries virens* as reported in USACE 2010.

E - Average for *Neries virens* as reported in ASTM E1688 and USACE 2010.

1.4 Summary

It should be noted that while the *M. nasuta* tissue PAH concentrations were higher than the measured *N. virens* tissue concentrations, none of the sediment PAH compounds evaluated were predicted to bioaccumulate above the "effects" benchmark TRVs for either species. It is recognized that bivalves accumulate PAHs due to their inability to metabolize them (Sirota and Uthe 1981), whereas fish and other invertebrates are capable of metabolizing PAHs, and typically have lower tissue PAH levels (Reichert et al. 1985; Lemaire et al. 1990); this is supported by the current bioaccumulation test results in which *M. nasuta* tissues exhibited higher PAH concentrations than did *N. virens*. Due to the ability of most organisms to metabolize PAHs, it is generally agreed that trophic transfer and biomagnification of PAHs is not toxicologically problematic for food webs (Suedel et al 1994); this is supported by studies showing that while primary consumers and detritivores can accumulate PAHs, predators usually contain low levels (Clement et al. 1994; Hellou et al. 1991; Lemaire et al. 1993; Niimi and Dookran 1989). The relevant peer-reviewed literature regarding the bioaccumulation of PAHs in the aquatic environment suggests that the predicted PAH accumulation in benthic organism tissues resulting from exposure to these Z-layer sediments would ***not*** have an adverse effect on upper trophic level consumers.

Furthermore, the sediment shoaling/deposition rate will reduce benthic organism exposure to the Z-layer, or post-dredge mudline. Shoaling rates in the Port's Berths 1, 2, 3 and 4 tend to run between approximately 0.5-1 foot per year*. However, in the first period of heavy shoaling following a dredging episode (generally springtime), the newly dredged berths tend to fill in faster-than-normal at a rate of approximately 1-2 inches per month*. Therefore, if the berths were dredged to the minimum required depth of -34 feet MLLW during the fall 2015 dredging episode, a reasonable assumption would be that the exposed surfaces would be covered by 3 to 6 inches of newly shoaled/deposited ambient Bay material within 3 months (Moffatt and Nichol 2015).

* The shoaling rates described above were developed by comparing pre- and post- dredging surveys from the Port's 2010 dredging episode, a condition survey taken in December 2010, and several Corps surveys of the Federal Channel that contained soundings within the berth areas. These rates are a general average, as the shoaling rate in any given year can vary depending on weather conditions and dredging operations of the adjacent Federal Channel (Moffatt and Nichol 2015).

1.5 References

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